Vector Meson production in ALICE at the LHC

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Abstract. ALICE is the experiment dedicated to the study of the quark gluon plasma in heavy-ion collisions at the LHC. The study of the in-medium properties of light vector mesons (ρ, ω and ϕ) through their leptonic decay channel is interesting because leptons have negligible final state interactions. Indeed, they leave the hadronic medium with no distortions providing a clean tool to look into the medium. The pp collisions are used as baseline for the heavy ion study. We present the results of light vector meson measurements in pp collisions at $\sqrt{s} = 7$ TeV in the dielectron and dimuon channels. The dielectron study is performed in the rapidity range |y| < 0.9 and the dimuon one for a rapidity range -4.0 < y < -2.5. Methods used for background subtraction are described. p_T distributions of ϕ and $\rho + \omega$, as well as the ratio of the ϕ yield over the $\rho + \omega$ yield will be shown. The status of the Pb-Pb analysis at $\sqrt{s_{NN}} = 2.76$ TeV is also presented.

The vector meson study in ALICE is performed among others in the dilepton decay channel. Leptons are interesting to probe the QGP because of their negligible final state interactions. In this proceeding, the focus will be on inclusive light vector mesons (ρ, ω, ϕ) analysis. Light vector mesons are usefull tools to study the QGP. Indeed, thanks to their short lifetime (between 1.3 fm/c for the ρ to 46 fm/c for the ϕ) [1], their yields and spectral functions should be modified by the hot hadronic and QGP medium. The lifetime of the ρ is even more interesting as it is shorter than the QGP one at LHC (10 fm/c). The ρ spectral function can be used to reveal in-medium modifications of hadron properties close to the QCD phase boundary, and to study the chiral symmetry restoration. Strangeness enhancement can be accessed through the measurement of the ratio of the ϕ yield over $\rho + \omega$ yield as a function of the centrality in Pb-Pb collisions. Vector meson study in pp collisions is used as a baseline for the heavy ion study, and allows to tune particle production models in a new energy domain.

ALICE (A Large Ion Collider Experiment) [2] is made of three parts: a central barrel embedded in a 0.5 T solenoidal magnetic field, a muon spectrometer, and several detectors at small angles. The central barrel consists of a Time Projection Chamber (TPC) and also an Inner Tracking System (ITS) allowing charged particle trajectography. It contains several detectors for Particle IDentification (PID) such as the Time Of Flight detector (TOF), the High Momentum Particle IDentification system (HMPID), the Transition Radiation Detector (TRD) and the ElectroMagnetic CALorimeter (EMCAL). The trajectography is performed in the pseudo-rapidity domain $|\eta|$< 0.9. The muon spectrometer covers the acceptances -4 < η < -2.5. It is composed of hadronic absorbers, a dipole magnet delivering a field of 0.7 T, ten proportionnal multi-wire chambers grouped in five tracking stations, four resistive plate chambers for triggering, and an iron wall to filter muons. Among the detectors at small angles we have to mention the

VZERO, FMD and ZDC detectors. The minimum bias trigger in ALICE in pp collisions is built asking at least one hit in the two first layers of the ITS (SPD) or in the VZERO scintillators. A single muon trigger corresponding to a coincidence of minimum bias trigger with a muon in the trigger chamber of the spectrometer also exits. During the data taking of 2010, 800 millions minimum bias interactions and 100 millions muon triggers were recorded. For the Pb-Pb data taking, the minimum bias trigger is the logical AND of the SPD and the two scintillator arrays of VZERO. The efficiency for Pb-Pb interactions is larger than 97% and after physic selection based on VZERO and ZDC analysis, electromagnetic contamination in the centrality bin 0-80% is negligible.

Inclusive light vector meson production in the dielectron channel in pp collisions at $\sqrt{s} = 7$ TeV

The low mass dielectron analysis is performed in the central barrel of ALICE for pseudo-rapidity $|\eta| < 0.9$. Thanks to its excellent PID, ALICE can isolate a clean sample of electrons with small contaminations. In the present analysis, TPC and TOF are used for single electron identification. In the future, EMCAL and TRD will be used to extend the analysis at higher p_T. Several processes contribute to the dielectron spectra at low masses: $\pi^0 \rightarrow e^+e^-\gamma$, $\eta \rightarrow e^+e^-\gamma$, $\eta' \rightarrow e^+e^-\gamma$, $\rho \rightarrow e^+e^-$, $\omega \rightarrow e^+e^-$, $\omega \rightarrow e^+e^- \pi^0$, $\phi \rightarrow e^+e^-$, $\phi \rightarrow e^+e^- \eta$. The π^0 Dalitz decay is an important source of background and can be rejected by selecting tracks with an invariant mass $M_{inv} > 200$ MeV/c^2. A cut on the opening angle of the dielectron is also applied to reject photon conversion. Other global qualitative cuts are applied to select the tracks ($p_T > 1$ GeV/c, cut on the Distance of Closest Approach to reject secondary tracks). Invariant mass spectra were reconstructed and the background evaluated with the like sign electron pairs. The number of background pairs is given by $N_{+-} = 2 \times \sqrt{N_{++}N_{--}}$ where $N_{--}(N_{++})$ is the number of negative (positive) dielectron pairs respectively. The invariant mass plot was extracted from a data sample of 2.9×10^8 minimum bias events, (see Fig. 1 left). The plot is performed for variable bin sizes and is normalized to the number of events and bin size. Fig. 1 right is the invariant mass spectra after background subtraction. The light vector meson peaks are visible.

Inclusive light vector meson production in the dimuon channel in pp collisions at $\sqrt{s} = 7$ TeV

The low mass dimuon analysis is performed in the pseudo-rapidity range $-4 < \eta < -2.5$. The data sample corresponds to an integrated luminosity of 85 nb^{-1}. A cut on the pseudo-rapidity of the single muon is applied: -4 < η < -2.5. In order to obtain a clean sample of muons, only tracks matching a muon trigger track are selected. The background was evaluated using two methods: the like sign pair technique and the event mixing technique. For the like sign technique, the background evaluation is calculated as: $N_{+-} = 2 \times R\sqrt{N_{++}N_{--}}$ where $N_{--}(N_{++})$ is the number of negative (positive) dimuon pairs respectively. The R factor is defined as $R = \frac{A_{+-}}{\sqrt{A_{++}A_{--}}}$
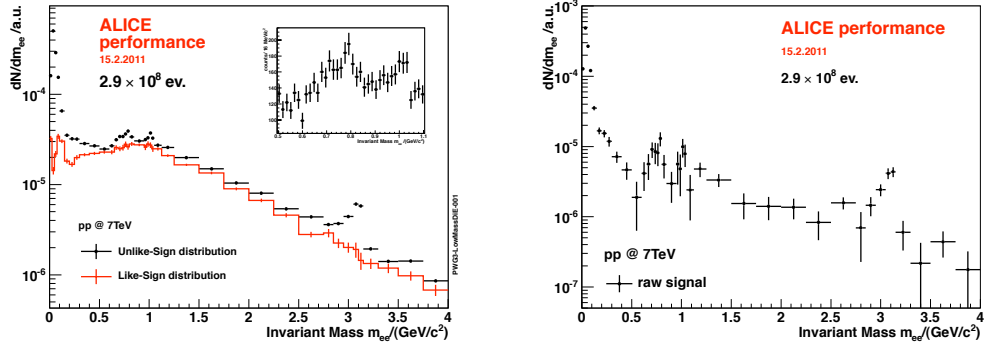
FIGURE 1. Left: Invariant mass spectra of dielectron opposite sign pairs in black. In red, the combinatorial background is evaluated with the like sign dielectron pairs. Right: Invariant mass spectra after background subtraction.

where A_{+-}, A_{++} and A_{--} are the acceptances for "+-","++" and "- -" pairs. The event mixing technique is based on the combination of muons coming from different events. Events containing only one muon, satisfying the same cuts as for datas, are mixed to construct uncorrelated dimuons. The event mixing spectrum is then normalized to the integral of the combinatorial background evaluated with the like sign pair technique. The two methods are in good agreement for muon pair $p_{\rm T}$ greater than 1 GeV/c. The invariant mass spectrum is extracted after background subtraction with the event mixing technique. The different contributions are fitted using an hadronic cocktail in realistic simulations, (Fig. 2 left). The free parameters of the fit are the normalizations of η, ω, ϕ and the charm. The ratio of the cross section of ρ over ω is fixed to 1. Realistic simulations were performed to extract acceptance $\times$ efficiency corrections. The corrected $p_{\rm T}$ distributions of $\rho + \omega$ (Fig. 2 middle) and ϕ (Fig. 2 right) were extracted and fitted by the function: $N_0 \left(\frac{p_T}{1+(\frac{p_T}{p_0})^2} \right)^n$. From the $p_{\rm T}$ spectra, the ratio $\frac{N_\phi}{N_\rho + N_\omega}$ was extracted (see Fig. 3 left). It is found to be 0.42 ± 0.02, constant with $p_{\rm T}$ and above Pythia value (0.31), and provide a reference value for a new tune of Pythia at 7 TeV.

Inclusive light vector meson production in the dimuon channel in $Pb - Pb$ collisions at $\sqrt{s_{NN}} = 2.76$ TeV

Concerning the Pb-Pb analysis, 6.6×10^6 minimum bias events were analyzed. A centrality selection was performed using VZERO scintillators. Fig. 3 right shows the invariant mass spectra of the dimuons, after some kinematics cuts, for a centrality bin corresponding to 40% to 80% of the total inelastic cross section. The background is fitted by a simple polynomial function and the resonances with pseudo-gaussian functions. The $\rho + \omega$ and ϕ resonances are observed. The analysis for other centrality bins is ongoing.
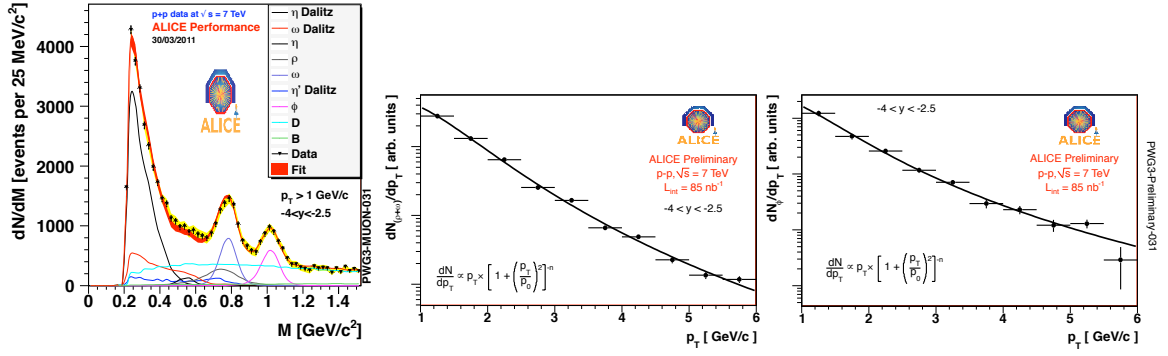
FIGURE 2. Left: Invariant mass spectra after background subtraction by event mixing (yellow band for systematics on background subtraction). The fit is obtained with an hadronic cocktail generator (red band for uncertainties on cocktail ingredients). Middle: Corrected p_T distribution of $\rho + \omega$. Right: Corrected p_T distribution of ϕ.
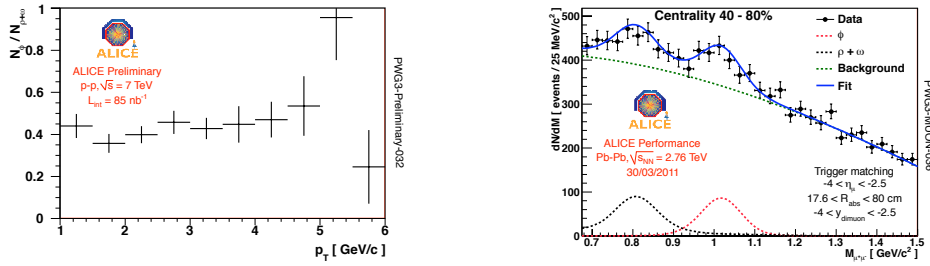

FIGURE 3. Left: Ratio $\frac{N_\phi}{(N_\rho + N_\omega)}$ as a function of p_T. Right: Dimuon invariant mass spectra in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, for peripheral events (40% to 80% of the total inelastic cross section).

Conclusion

Thanks to the excellent particle identification capabilities of ALICE, the electron identification allows the analysis of light vector mesons in the dielectron channel. The signal extraction has been performed in pp collisions at $\sqrt{s} = 7$ TeV and light vector mesons are visible in the invariant mass spectrum. In the dimuon channel, in pp collisions, the p_T spectra of ϕ and $\rho + \omega$ were extracted for a p_T range between 1 GeV/c and 6 GeV/c where the background is well understood and the statistic sufficient. The ratio of the ϕ yield over $\rho + \omega$ yield was measured and found to be 0.42 ± 0.02, constant with p_T and larger than Pythia predictions. In peripheral Pb-Pb collisions, at $\sqrt{s_{NN}} = 2.76$ TeV, light vector meson peaks are visible. The background behaviour is under study to extend the analysis to the most central collisions.

REFERENCES

1. C. Amsler et al. (Particle Data Group), Physics Letters B667, 1 (2008) and 2009
2. K. Aamodt et al., "The ALICE experiment at the CERN LHC", 2008, JINST 3 S08002.